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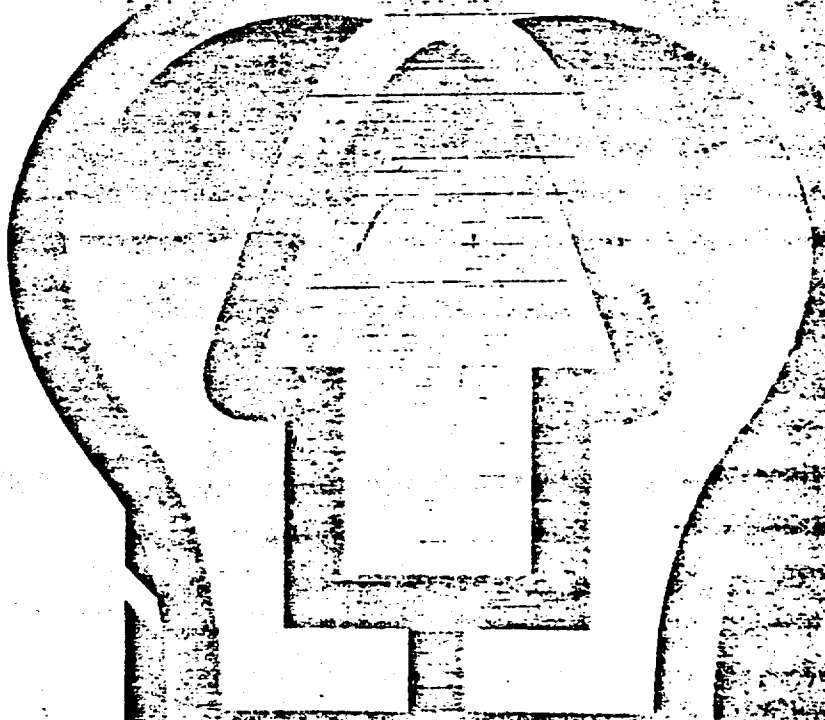

INDOOR AIR '90

BUILDING VENTILATION AND SMOKING POLICY EFFECTS ON INDOOR AIR QUALITY AND EMPLOYEE COMFORT AND HEALTH

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Indoor environmental conditions, occupant perceptions of ambient conditions, and reports of "sick" building syndrome (SBS) symptoms were compared for two office buildings: one where smoking is prohibited and one where smoking is restricted to areas with local air cleaning units. Few significant differences in pollutant concentrations were found between buildings. Perceptions of ambient conditions generally were less favorable in the "smoking restricted" building. Apart from mental fatigue, no differences in SBS symptoms were found between these buildings.

INTRODUCTION

Tobacco smoking in the workplace has been identified as a source of number of indoor air contaminants (1), and it has been reported that passive exposure to environmental tobacco smoke (ETS) may elevate the prevalence of "sick" building syndrome (SBS) symptoms (2). Many organizations have now implemented policies which either prohibit smoking or restrict this in the building, and some companies have also installed local air cleaning systems (LACS) to remove both particulates and volatile organics from air in smoking areas. This study investigated indoor air quality, perceptions of environmental conditions, and health reports in offices in a smoking prohibited (SP) office and a smoking restricted (SR) office with designated smoking areas with LACS.

MATERIAL & METHODS

Survey Buildings & General Survey Method

Two office buildings occupied by finance/insurance companies were compared. Neither

building had a history of indoor air quality problems. The SR building is a 40 story, urban office (54,000 m^3 gross:1,800 people), with a constant air volume ventilation system. Smoking in the offices was restricted to two smoking lounges with LACS (ceiling mounted units which remove particulate matter and odors via an aluminum pre-filter, ionizer and charcoal filter). The SP building is a four story "greenfield" site office (13,050 m^3 gross: 450 people), with a variable air volume ventilation system.

Each building was studied over a two day period in January. On each day two sites were surveyed in the morning and two in the afternoon All sites were in the open plan office areas in the SP building. In the SR building, morning and afternoon measurements were taken in the non-smoking open offices and also in the designated smoking lounges. At the same time a self-report questionnaire, based on previous research instruments for SBS investigations, was distributed at each site. Data on employee perceptions of ambient conditions (16 questions); work-related health and SBS symptoms (17 symptoms); occupational factors (12 questions); ETS exposure and smoking status; and personal information were collected. Answers to the environmental and health questions were made on the same frequency scale, applied to the past month in the building (never; 1-3 times/month; 1-3 times/week; every day). Questionnaire administration and collection were conducted by a researcher on the same day. The return rate was 61% (143/243) in the SP building, and 71% (259/364) in the SP building.

Indoor Air Quality Survey

Soundproofed briefcases containing indoor air quality sampling equipment were unobtrusively placed in each sampling area. One field blank for each sample was taken per building as well as a laboratory method blank per batch. All field and method blanks were found to be uncontaminated. The following pollutants were measured:

a. Nicotine - samples were collected by pumping air at 1 l min^{-1} through sorbent tubes containing XAD-4 resin for 3 hours. Nicotine was not measured in the SP building.
b. Respirable Suspended Particulate (2.5μ cutoff) - samples were taken using a single stage impactor (MSP Corporation) at a 4 l min^{-1} flow rate for 3 hours. Ultra-Violet particulate matter (UV-PM) was analyzed to estimate particulate matter from organic sources (3).
c. Formaldehyde - samples were collected by pumping air a 0.25 l min^{-1} through 2,4 dinitro -phenylhydrazine sorbent tubes for 3 hours (E.P.A. method TO-11).

Hourly measures of the following pollutants were taken with direct reading instruments: carbon monoxide (Interscan 4000); carbon dioxide (Riken 411); suspended particulates (TSI 3500 Piezobalance-3.5μ cutoff); lighting (Minolta Illuminance meter); temperature and relative humidity (Pacer Hygro-thermometer DH300).

Data Analysis

Chi-square analyses of the questionnaire data were performed using SPSSX. The physical environment data first were analyzed using the Generalized Linear Models procedure in SAS. The results reported here are a subset of a larger investigation which is still ongoing. For the SR building, a factorial model of smoking area designation and time-of-day (morning/afternoon) was fit to the environmental data. To test for interactions between buildings and time-of-day, chemical data were analyzed as a split unit design with true replication of time-of-day but no true replication of the building factor. The variation among sites for each building-time combination was used as the error term in testing for an interaction between building and time-of-day; all interactions were tested at a liberal alpha level of 0.1 (4). Independent sample t tests were then used to compare morning and afternoon pollutant concentrations in each building, and to compare pollutant concentrations between buildings separately for morning and afternoon samples. For most of these analyses unequal variance tests were performed.

RESULTS & DISCUSSION

There was no significant difference between the SP and SR buildings in the percentages of current smokers (17.4% vs. 15.4%), former smokers (12.4% vs. 10.5%), non-smokers (70.3% vs. 74.1%), or in the percentages of managers (13.9% vs. 13.9%), professional workers (18.3% vs. 21.2%), technical workers (16.3% vs. 12.4%), or clerical/secretarial workers (441.8% vs. 47.4%). There was a significant difference between the SP and SR buildings in the percentages of men (17.4% vs. 42.0%) and women (82.6% vs. 58.0%). Analysis of responses to the environmental questions showed that workers in the SR building found thermal conditions over the past month to be colder more often ($X^2 = 19.95$, df=3, $p<0.001$), whereas those in the SP building reported being satisfied with thermal conditions more often ($X^2 = 9.87$, df=3, $p<0.02$). In the SR building there were more complaints of frequent ventilation problems ($X^2 = 11.29$, df=3, $p<0.01$), of too little air movement ($X^2 = 10.48$, df=3 ,$p<0.01$), of dry air ($X^2 = 35.27$, df=3, $p<0.001$), of unpleasant odors ($X^2 = 10.15$, df=3, $p<0.02$), and of stale air ($X^2 = 15.24$, df=3, $p<0.002$) than in the SP building. Proportionally more people in the SR building reported experiencing infrequent glare problems ($X^2 = 12.94$, df=3, $p<0.005$) than in the SP building.

Health symptoms were defined as work-related only if the respondent indicated that the symptom got better on leaving the building. There were no significant differences between the SP and SR buildings in any work-related symptoms (table 1), except for "mental fatigue" ($X^2 = 14.22$, df=3, $p<0.003$).

The indoor environment data are summarized in tables 2 and 3. Data for carbon monoxide, carbon dioxide,and formaldehyde were transformed (natural log) because these data appeared to be lognormal (the variance varied with the mean). For computational purposes a value of 10^{-4} was added to each carbon monoxide reading since there were zero readings. There were no significant differences between buildings for morning samples for any pollutant. There was no significant difference in carbon dioxide and UV-PM between buildings for the afternoon samples. Afternoon concentrations of carbon monoxide (equal variance $t = 3.34$, $df=4$, $p<0.03$) and formaldehyde ($t = 4.37$, $df=3.8$, $p<0.01$) were higher in the SR building. Comparisons between morning and afternoon samples for carbon monoxide, carbon dioxide, formaldehyde, and UV-PM were not significant within either building. Analyses of the hourly data for particulates, air temperature, relative humidity, and illumination showed no significant differences between morning and afternoon conditions in the SP building. There were no morning/afternoon differences in particulates, relative humidity, or illumination for the SR building; however, air temperature was significantly higher in the afternoon in this building ($t = 15.81$, $df=1.4$, $p<0.03$).

Comparisons between buildings showed no morning differences, except for relative humidity ($t = 5.04$, $df=3.7$, $p<0.01$). In the afternoon, there were no differences between the buildings for carbon dioxide, or particulates; but there were significant differences for formaldehyde ($t = 4.37$, $df=3.8$, $p<0.01$), air temperature ($t = 4.30$, $df=3.2$, $p<0.02$), relative humidity ($t = 2.90$, $df=3.6$, $p<0.05$), illumination ($t = 6.03$, $df=1.8$, $p<0.05$), and UV-PM (equal variance $t = 29.40$, $df=1$, $p<0.02$).

In the SR building, there were no significant differences in pollutant concentrations between morning and afternoon samples for the designated smoking areas. Comparisons of designated smoking and open-office areas showed no morning or afternoon differences in the concentrations of carbon monoxide, carbon dioxide, air temperature, relative humidity, or illumination. However, morning data showed a significant difference in concentrations of particulates ($t = 11.8$, $df=1.1$, $p<0.05$), and marginally significant differences in concentrations of UV-PM ($t = 6.31$, $df=1.0$, $p<0.1$), and nicotine ($t = 8.15$, $df=1.1$, $p<0.07$). For the afternoon samples, these comparisons showed no significant differences in concentrations of particulates or UV-PM; but there were marginally significant differences in concentrations of formaldehyde ($t = 6.58$, $df=2.0$, $p<0.07$) and nicotine ($t = 8.08$, $df=1.0$, $p<0.08$).

CONCLUSIONS

Perceptions of environmental conditions were generally less favorable for the SR building than the SP building. Pollutant concentrations for carbon monoxide, carbon dioxide, formaldehyde, and UV-PM were significantly higher for afternoon samples in the SR than in

Nicotine also was measurable in the SR building. However, except for mental fatigue, there were no significant differences in the prevalence of work-related SBS symptoms between buildings. These results suggest that restricting smoking to designated areas, which have local air filtration systems, is effective in minimizing the impact of environmental tobacco smoke on indoor air quality, and that SBS is not caused by exposure to environmental tobacco smoke in offices.

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Table 1 The prevalence of SBS symptoms experienced at least once in the past month.

SBS symptoms	SP building	SR building
Dry eyes	39.0%	43.9%
Sore eyes	40.1%	48.6%
Sore throat	23.6%	26.2%
Stuffy nose	32.4%	32.9%
Runny nose	25.2%	24.5%
Headache	49.4%	44.4%
Chest tightness	8.9%	10.7%
Lethargy	31.7%	33.8%
Mental fatigue	57.5%	41.5% p<0.002

Table 2 Concentrations of carbon monoxide, carbon dioxide, and formaldehyde in the offices. (mean ppm value is the mean back transformed from the log)

		AM samples			PM samples		
		Mean		Mean	Mean		Mean
Pollutant	Building	log	SE	ppm	log	SE	ppm
Carbon monoxide	SP	0.0	0.0	0.0	0.0	0.0	0.0
	SR (Office)	0.9	0.3	2.5	0.5	0.3	1.7
	SR (Smoking)	1.0	0.3	2.8	1.0	0.3	2.6
Carbon dioxide	SP	6.38	0.04	589	6.41	0.04	610
	SR (Office)	6.73	0.12	845	6.46	0.04	642
	SR (Smoking)	6.53	0.00	684	6.58	0.07	717
Formaldehyde	SP	-2.91	0.14	0.023	-3.06	0.07	0.019
	SR (Office)	-3.78	0.52	0.008	-3.39	0.03	0.012
	SR (Smoking)	-3.09	0.08	0.018	-2.88	0.07	0.023

Table 3 Concentrations of ETS pollutants and ambient conditions in the offices.

		AM samples		PM samples	
Pollutant	Building	Mean	SE	Mean	SE
Nicotine ($\mu g\ m^{-3}$)	SR (Office)	0.0	0.0	0.0	0.0
	SR (Smoking)	27.2	3.2	41.2	5.0
Particulates:	SP	20	0.0	10	10
(3.5μ - $\mu g\ m^{-3}$)	SR (Office)	40	10	40	10
	SR (Smoking)	110	0.0	140	20
Particulates:	SP	N/A	N/A	N/A	N/A
(2.5μ - $\mu g\ m^{-3}$)	SR (Office)	200.0	0.0	300.0	100.0
	SR (Smoking)	350.0	50.0	400.0	0.0
UVPM ($\mu g\ m^{-3}$)	SP	0.0	0.0	0.0	0.0
	SR (Office)	9.0	1.0	7.0	0.0
	SR (Smoking)	120.0	18.0	185.0	52.0
Temp. (°C)	SP	24.0	0.1	23.5	0.3
	SR (Office)	23.7	0.0	24.6	0.1
	SR (Smoking)	23.0	0.5	24.2	0.2
Relative Humidity (%)	SP	36.5	2.3	35.5	4.6
	SR (Office)	21.9	1.8	21.4	1.5
	SR (Smoking)	22.4	0.7	21.7	1.8
Illumination (lux)	SP	388	100	304	34
	SR (Office)	425	148	712	58
	SR (Smoking)	664	102	456	344